MODIFICATION OF ELECTROPHYSICAL PROPERTIES OF SILICON-BASED SEMICONDUCTOR STRUCTURES UNDER THE INFLUENCE OF LASER BEAMS

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Abstract. The article investigates the modification of electrophysical properties of silicon-based semiconductor structures under laser irradiation. It is shown that laser treatment significantly affects electrical conductivity, surface characteristics, and energy efficiency of semiconductor materials. The obtained results expand the possibilities of effective application of semiconductor elements in microelectronics, power engineering, and modern technical devices.

Key words*:* laser radiation, semiconductor, silicon, electrical conductivity, power engineering, electrophysical properties.

The rapid development of the electric power industry, microelectronics, and mechanical engineering is dramatically increasing the demand for high-performance semiconductor materials. Modern devices used in the generation, transmission, distribution, and management of electrical energy are primarily based on semiconductor elements, and their performance is directly dependent on the electrical properties of the materials. Therefore, monitoring and improving the electrical conductivity, surface condition, and energy performance of semiconductors is a pressing scientific and technical challenge.

Today, in the energy and technology sectors, where high efficiency, compactness, and reliability are required, developing new properties for semiconductor materials is of great importance. In particular, the use of contactless, high-precision, and localized laser technologies is seen as a promising approach to addressing this issue.

Among semiconductor materials, silicon stands out for its widespread use, technological convenience, relative cheapness, and stable electrical properties. Silicon-based semiconductors are widely used in inverters, amplifiers, power supplies, power electronics elements, and control and measuring devices. The energy efficiency of these devices largely depends on the electrical conductivity, defect concentration, and surface state of silicon, and their modification is a pressing issue.

Bugungi kunda lazer mikro va nanostrukturalarini yaratish jarayoni yarimo'tkazgichli mikroelektronikada keng qo'llaniladi. Dunyo bo'ylab ko'plab tadqiqot markazlaridagi bir qator yetakchi olimlar lazer nurlari yordamida kremniy yuzasida mikro va nanostrukturalarni hosil qilishning istiqbolli usullarini ishlab chiqdilar.

The development of laser technologies has made it possible to process semiconductor materials without contact and with high precision. Using laser beams, it is possible to change the structure of the surface of the material, create or eliminate defects, as well as modify the electrical properties. This research is devoted to the study of the electrophysical properties of silicon-based semiconductors under the influence of laser beams.

Many scientific studies have been conducted on the study of the electrophysical properties of semiconductor materials. S.M. Sze has described in detail the physical foundations

of semiconductor devices, in which the influence of electrical conductivity and defect states is widely analyzed [1]. J.F. Ready has shown in his studies the potential applications of laser technologies in industry and technology [2].

Local scientists have also studied the modification of the physical properties of semiconductor materials under the influence of laser beams [3]. These works confirm the prospects for the application of laser technologies in the energy and technical sectors. However, a thorough analysis of the electrophysical properties of silicon-based semiconductors from the point of view of energy efficiency remains relevant.

Monocrystalline silicon-based semiconductor wafers were chosen as the object of research. The samples were treated with laser beams at different energy densities. Changing the parameters of laser radiation has a significant impact on the physical processes occurring on the surface and in the volume of the semiconductor.

It is known that laser light can cause various changes in the crystal structure of a semiconductor, which in turn leads to changes in the electrophysical and optical properties of the material.

During laser processing, physical processes occurring on the surface and in the volume of the semiconductor are observed. To evaluate the electrophysical properties, the samples are tested for electrical conductivity, resistance, and surface condition. Measurements are carried out under standard laboratory conditions. The results obtained are evaluated using comparison and analysis methods. A Nd:YAG laser with a frequency of 12.5 Hz, power P = 1.0 MW, and wavelength λ = 1.064 nm was used to irradiate the samples. The diameter of the laser spot was 3 mm, and a single-point and multi-point method was used to irradiate the samples.

Studies have shown that under the influence of laser light, the electrical conductivity of silicon-based semiconductors changes significantly compared to the initial state. Laser-treated samples have a higher conductivity compared to the initial state. This is explained by the formation of new energy states in the surface layer under the influence of laser energy. That is, when laser-treated samples are used in power devices, there is a decrease in electrical losses. This increases the overall efficiency of semiconductor elements.

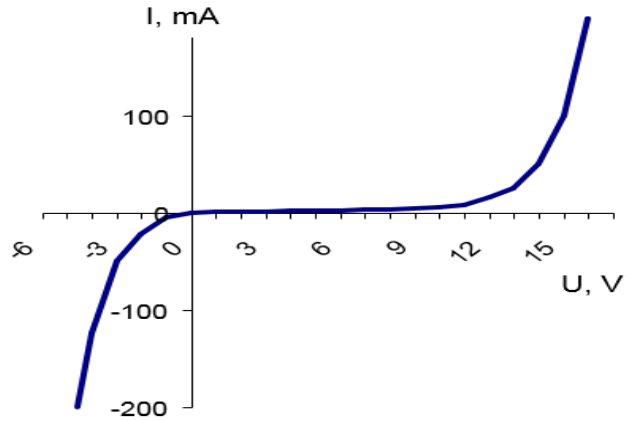

Figure 1. Volt-ampere characteristic of a laser-irradiated unoxidized single-crystal silicon sample.

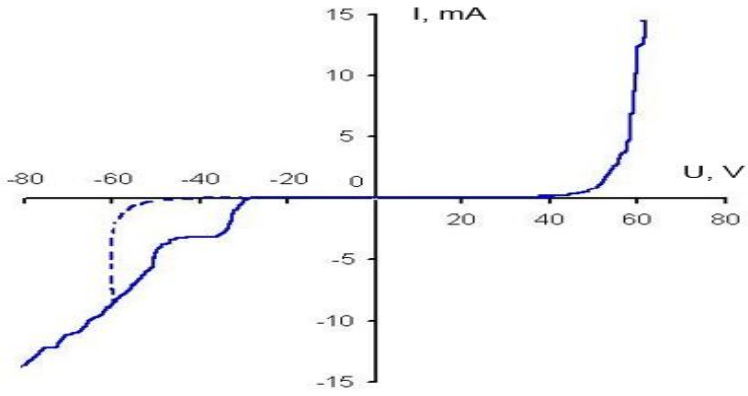

Figure 2. Volt-ampere characteristic of a laser-irradiated oxidized single-crystal silicon sample.

Irradiation of unoxidized single-crystal silicon with laser light results in a cathodoluminescence spectrum corresponding to an energy of 2.25 eV, indicating the presence of silicon nanoclusters in the silicon-oxide structure.

An additional spectral peak appears in the cathodoluminescence spectrum of oxidized samples, indicating that this is due to the formation of a new type of oxide layer.

As a result of examining the volt-ampere characteristic of the irradiated areas, it was found that the inverse volt-ampere characteristic in the samples oxidized before irradiation had a deviation from the standard state.

The results obtained provide an opportunity to increase the energy efficiency of semiconductor elements used in power generation devices.

The results obtained demonstrate that laser technology can be used to selectively control the electrophysical properties of semiconductor materials. This method is important for improving the efficiency of inverters, amplifiers, and control devices used in the energy sector.

Laser-modified semiconductors also have long-term performance stability, extending the service life of technical devices.

It has been found that it is possible to change the electrophysical properties of silicon-based semiconductors under the influence of laser beams. The results of the research serve as a scientific basis for the effective use of semiconductor materials in the energy and technical sectors. The use of laser technologies can increase the energy efficiency of electrical devices.

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